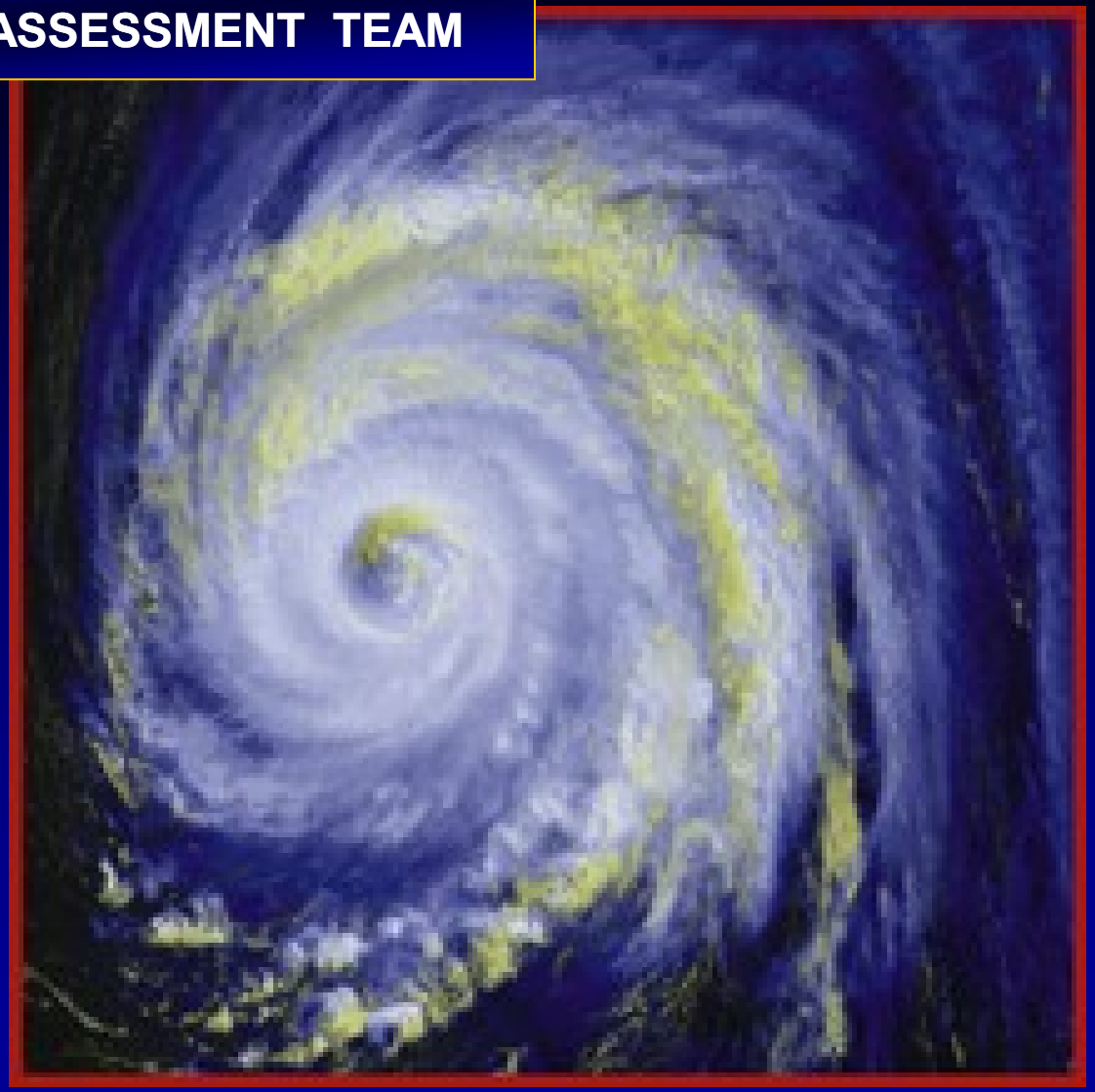
BUILDING PERFORMANCE ASSESSMENT TEAM

Hurricane Fran in North Carolina



OBSERVATIONS, RECOMMENDATIONS, AND TECHNICAL GUIDANCE

FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

FEMA Building Performance Assessment Teams

- Team Objectives
  - Inspect damage to buildings
  - Assessment performance of buildings
  - Evaluate design and construction practices
  - Evaluate code requirements and enforcement
  - Make recommendations as necessary

FEMA Building Performance Assessment Teams

- Team Members
  - Representatives of public and private sectors and expertise in:
    - structural and civil engineering
    - building design and construction
    - code development and enforcement

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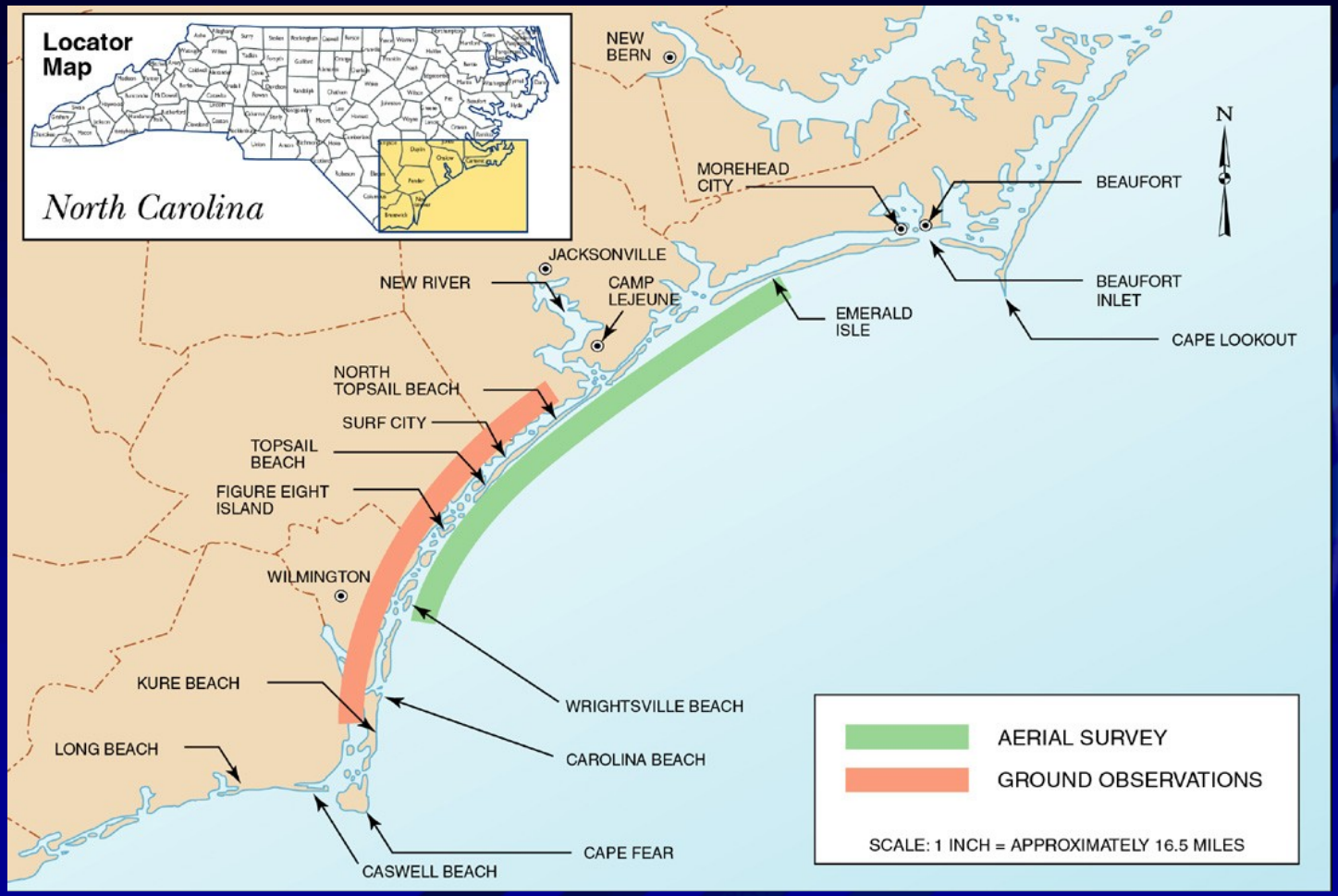

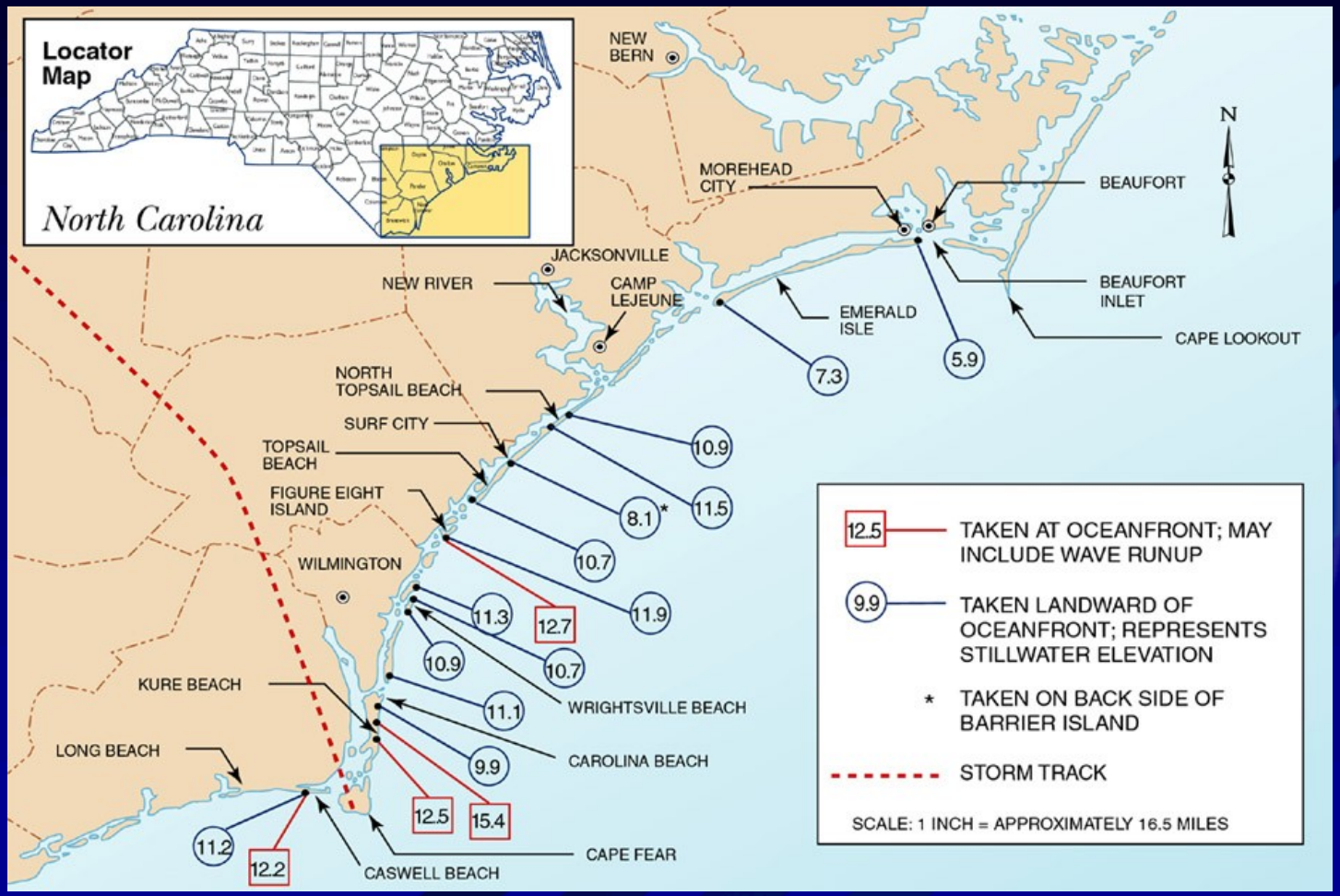
Locator Map
North Carolina
NEW BERN
MOREHEAD CITY
BEAUFORT
N
JACKSONVILLE
NEW RIVER
CAMP LEJEUNE
BEAUFORT INLET
EMERALD ISLE
CAPE LOOKOUT
7.3
5.9
NORTH TOPSAIL BEACH
SURF CITY
TOPSAIL BEACH
FIGURE EIGHT ISLAND
10.9
11.5
8.1 *
10.7
WILMINGTON
11.9
11.3
12.7
10.9
10.7
KURE BEACH
11.1
WRIGHTSVILLE BEACH
LONG BEACH
9.9
CAROLINA BEACH
12.5
15.4
11.2
12.2
CAPE FEAR
CASWELL BEACH
12.5 TAKEN AT OCEANFRONT; MAY INCLUDE WAVE RUNUP
9.9 TAKEN LANDWARD OF OCEANFRONT; REPRESENTS STILLWATER ELEVATION
* TAKEN ON BACK SIDE OF BARRIER ISLAND
STORM TRACK
SCALE: 1 INCH = APPROXIMATELY 16.5 MILES

Observations

- **Building Types**
  - Wood-frame on pilings
  - Wood-frame on slab-on-grade foundations
  - Wood-frame on continuous masonry wall foundations
  - Manufactured homes on dry-stacked masonry block foundations

Observations

- Damaged Observed
  - Leaning and collapsed buildings
  - Undermined continuous foundation walls
  - Collapsed decks, porches, and roof overhangs
  - Broken vertical foundation members
  - Broken cross-bracing on piling foundations

Observations

- **Damaged Observed** *(continued)*
  - **Undermined below-building concrete slabs**
  - **Exposed septic tanks**
  - **Loss of electrical, water, and sewer lines**
  - **Collapsed AC/heat pump compressor platforms**

Observations

- Damaged Resulted From:
  - Erosion of frontal dunes and beach profile
  - Localized scour around pilings and continuous foundations
  - Velocity flow, wave action, and debris impact on:
    - vertical foundation members
    - cross-bracing of piling foundations
    - walls of below-building enclosures

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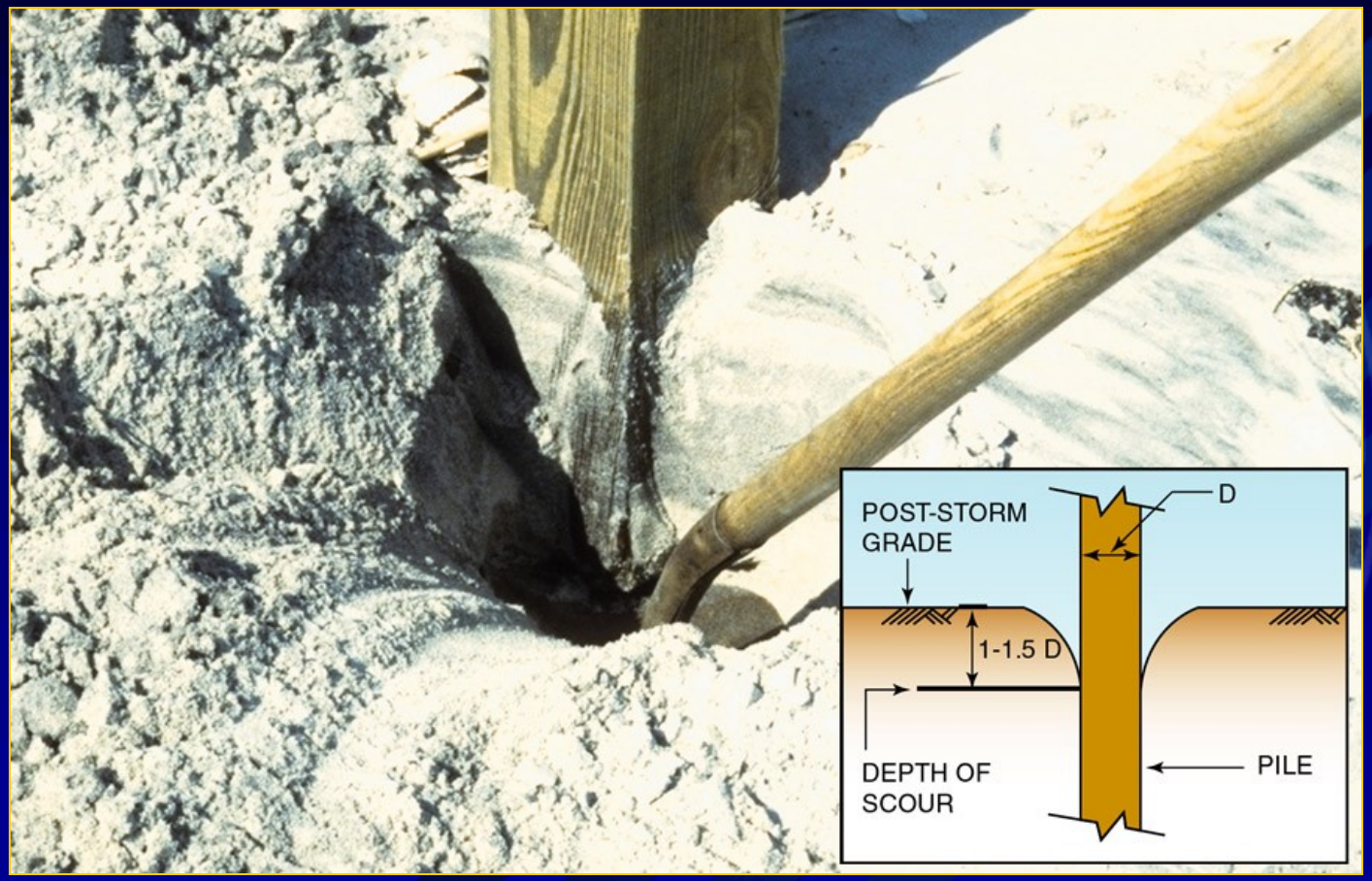
Observations

- Erosion
  - Affected oceanfront buildings
  - Lowered beach profile 2 to 3 feet
  - Lowered grade 4 to 6 feet below buildings
  - Exacerbated by previous effects of Bertha


PRE-STORM
GRADE

Observations

- Localized Scour
  - Affected oceanfront and landward buildings
  - Depth of scour = 1 to 1.5 times diameter or width of vertical member


POST-STORM
GRADE
D
1-1.5 D
DEPTH OF
SCOUR
PILE

Observations

- **Erosion Plus Localized Scour**
  - Completely exposed, or reduced embedment depth of foundations
  - Resulted in collapse of over 100 oceanfront buildings
  - Resulted in many other buildings leaning

FEDERAL EMERGENCY MANAGEMENT AGENCY

BUILDING PERFORMANCE ASSESSMENT TEAM

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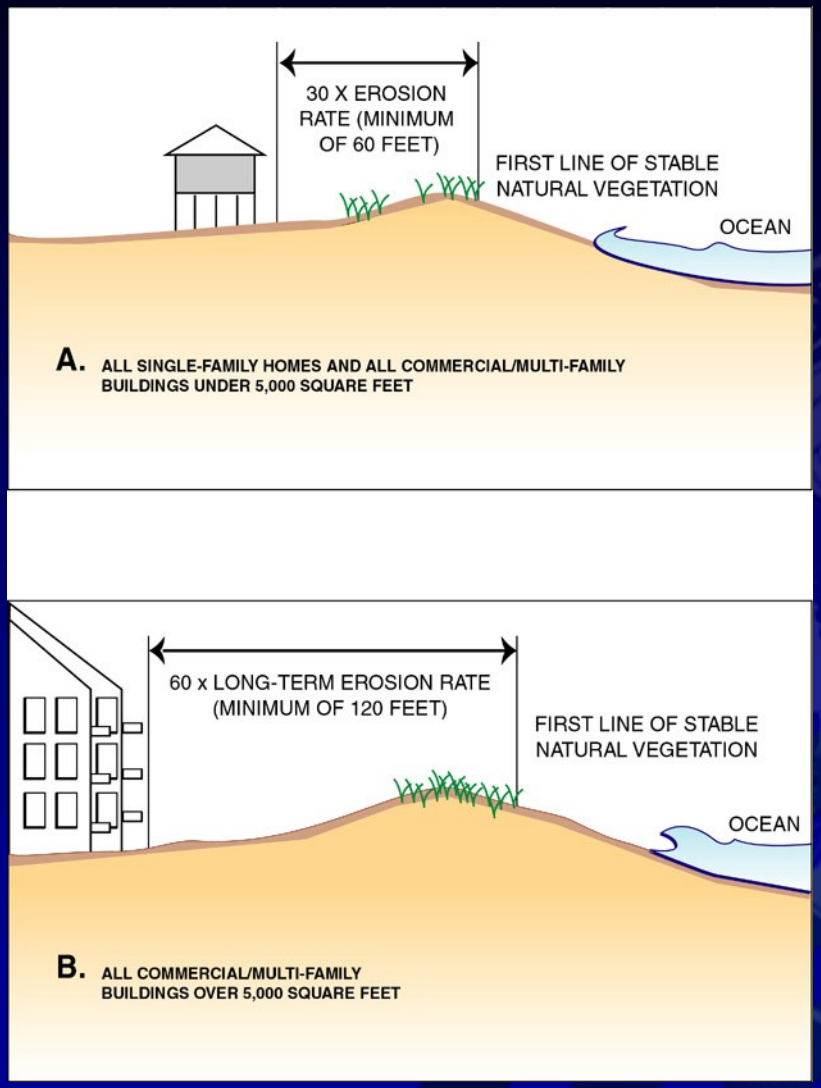
BUILDING PERFORMANCE ASSESSMENT TEAM

Observations

- Applicable Codes and Requirements
  - North Carolina Coastal Area Management Act (CAMA) - building setback for erosion protection
  - North Carolina State Building Code - piling embedment depth
  - NFIP requirements

Observations

- **Minimum CAMA Setback Requirements (from first line of stable natural vegetation)**
  - **Single-family homes and commercial/ multi-family buildings <5,000 square feet**
    - **30 x erosion rate (minimum of 60 feet)**
  - **Commercial/multi-family buildings >5,000 square feet**
    - **60 x long-term erosion rate (minimum 120 feet)**


30 X EROSION
RATE (MINIMUM
OF 60 FEET)
FIRST LINE OF STABLE
NATURAL VEGETATION
OCEAN
A. ALL SINGLE-FAMILY HOMES AND ALL COMMERCIAL/MULTI-FAMILY
BUILDINGS UNDER 5,000 SQUARE FEET
60 x LONG-TERM EROSION RATE
(MINIMUM OF 120 FEET)
FIRST LINE OF STABLE
NATURAL VEGETATION
OCEAN
B. ALL COMMERCIAL/MULTI-FAMILY
BUILDINGS OVER 5,000 SQUARE FEET

Observations

- State Building Code Embedment Requirements for Main Structure Pilings
  - Pre-1986 - 8 feet below grade for all structures
  - Post-1985 - 16 feet below grade or -5 feet m.s.l., whichever is shallower, for structures in erosion-prone areas

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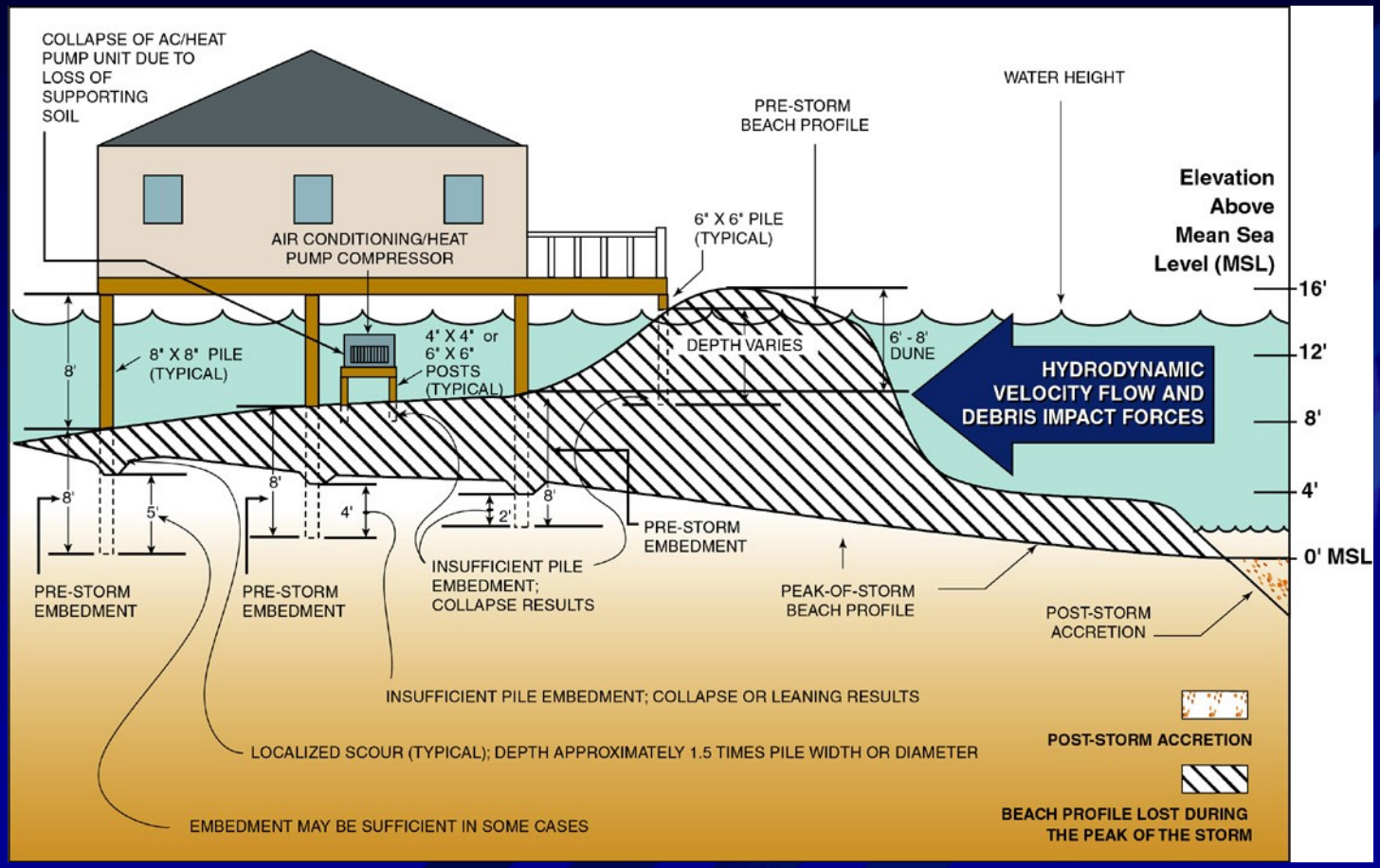
BUILDING PERFORMANCE ASSESSMENT TEAM


COLLAPSE OF AC/HEAT PUMP UNIT DUE TO LOSS OF SUPPORTING SOIL
AIR CONDITIONING/HEAT PUMP COMPRESSOR
8' X 8' PILE (TYPICAL)
4' X 4' or 6' X 6' POSTS (TYPICAL)
6' X 6' PILE (TYPICAL)
PRE-STORM BEACH PROFILE
WATER HEIGHT
DEPTH VARIES
6' - 8' DUNE
HYDRODYNAMIC VELOCITY FLOW AND DEBRIS IMPACT FORCES
Elevation Above Mean Sea Level (MSL)
16'
12'
8'
4'
0' MSL
8'
8'
5'
8'
4'
2'
8'
PRE-STORM EMBEDMENT
PRE-STORM EMBEDMENT
INSUFFICIENT PILE EMBEDMENT; COLLAPSE RESULTS
PRE-STORM EMBEDMENT
PEAK-OF-STORM BEACH PROFILE
POST-STORM ACCRETION
INSUFFICIENT PILE EMBEDMENT; COLLAPSE OR LEANING RESULTS
LOCALIZED SCOUR (TYPICAL); DEPTH APPROXIMATELY 1.5 TIMES PILE WIDTH OR DIAMETER
EMBEDMENT MAY BE SUFFICIENT IN SOME CASES
POST-STORM ACCRETION
BEACH PROFILE LOST DURING THE PEAK OF THE STORM

Observations

- **Effect of Federal and State Requirements**
  - **Buildings that met CAMA,1986 State Building Code, and NFIP requirements outperformed all others**
  - **Post-Fran piling embedment depth study conducted on Topsail Island by FEMA contractor indicated value of deeper embedment requirement of 1986 State Code**

FEDERAL EMERGENCY MANAGEMENT AGENCY

BUILDING PERFORMANCE ASSESSMENT TEAM

Observations

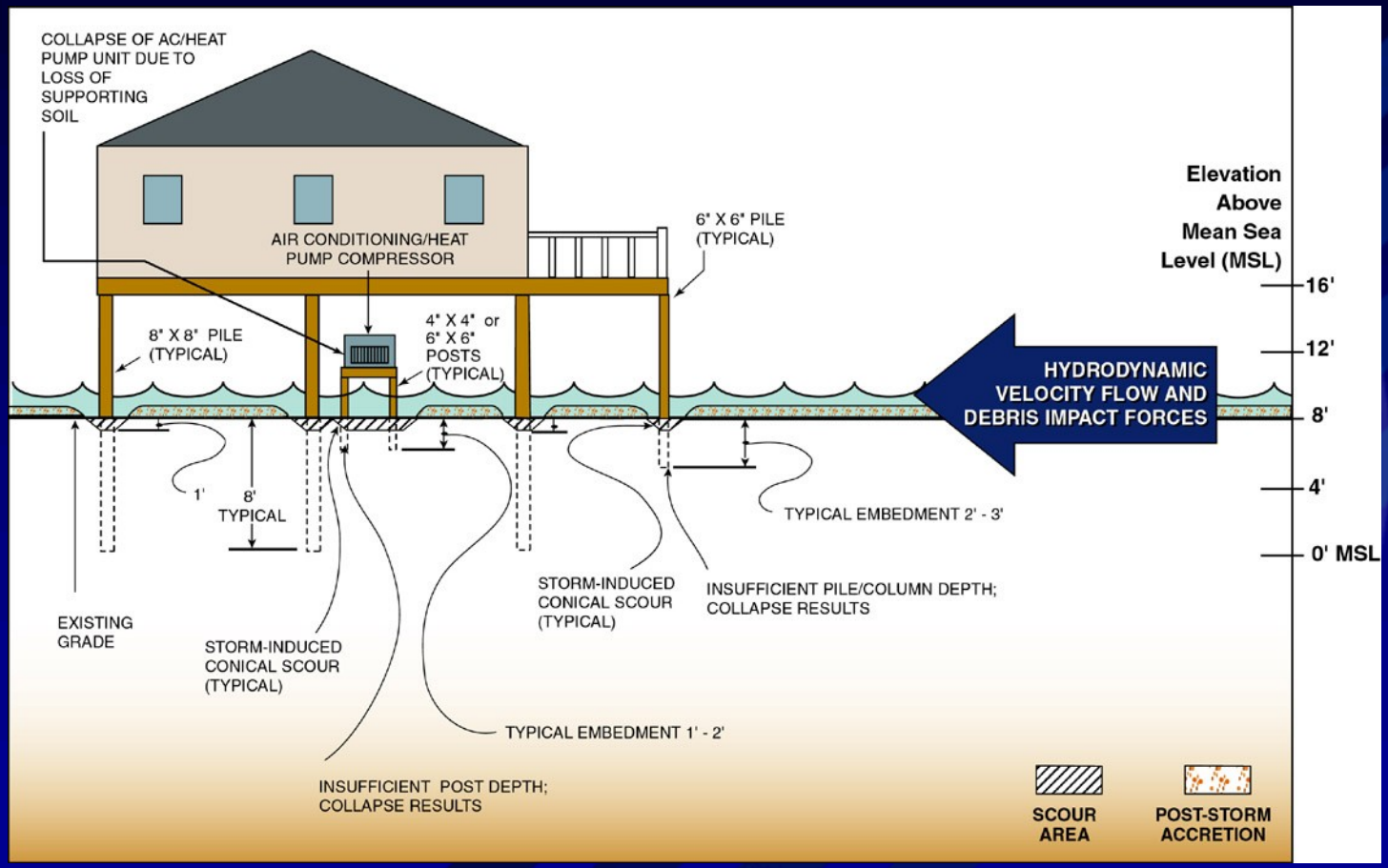
- BPAT concerns about construction practices involve:
  - Piling and post embedment depths
  - Use of cross-bracing
  - Grade of lumber for pilings and cross-bracing
  - Use of continuous foundation walls

Observations

- **BPAT concerns about construction practices involve:** *(continued)*
  - **Installation of breakaway walls for below-building enclosures**
  - **Construction of below-building concrete slabs**
  - **Installation of utility system components**

Observations

- Piling and Post Embedment Depths
  - Shallow embedment depths on pre-1986 buildings
  - Shallow embedment depths on decks, porches, and roof overhangs on pre-1986 and post-1985 buildings
  - Shallow post embedment depths for AC/ heat pump compressor platforms


COLLAPSE OF AC/HEAT PUMP UNIT DUE TO LOSS OF SUPPORTING SOIL
AIR CONDITIONING/HEAT PUMP COMPRESSOR
6" X 6" PILE (TYPICAL)
8" X 8" PILE (TYPICAL)
4" X 4" or 6" X 6" POSTS (TYPICAL)
Elevation Above Mean Sea Level (MSL)
16'
12'
8'
4'
0' MSL
HYDRODYNAMIC VELOCITY FLOW AND DEBRIS IMPACT FORCES
1'
8' TYPICAL
TYPICAL EMBEDMENT 2' - 3'
EXISTING GRADE
STORM-INDUCED CONICAL SCOUR (TYPICAL)
STORM-INDUCED CONICAL SCOUR (TYPICAL)
INSUFFICIENT PILE/COLUMN DEPTH; COLLAPSE RESULTS
TYPICAL EMBEDMENT 1' - 2'
INSUFFICIENT POST DEPTH; COLLAPSE RESULTS
SCOUR AREA
POST-STORM ACCRETION

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Observations

- Use of Cross-Bracing
  - Installed perpendicular to velocity flow and wave action
- Grade of Lumber for Pilings and Cross-Bracing
  - Use of lumber with excessive numbers of knots, cracks, or other defects for vertical foundation members and cross-bracing

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Observations

- Continuous Foundation Walls
  - Use in A-zone areas susceptible to high velocity flow


Scour Below Footing

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Observations

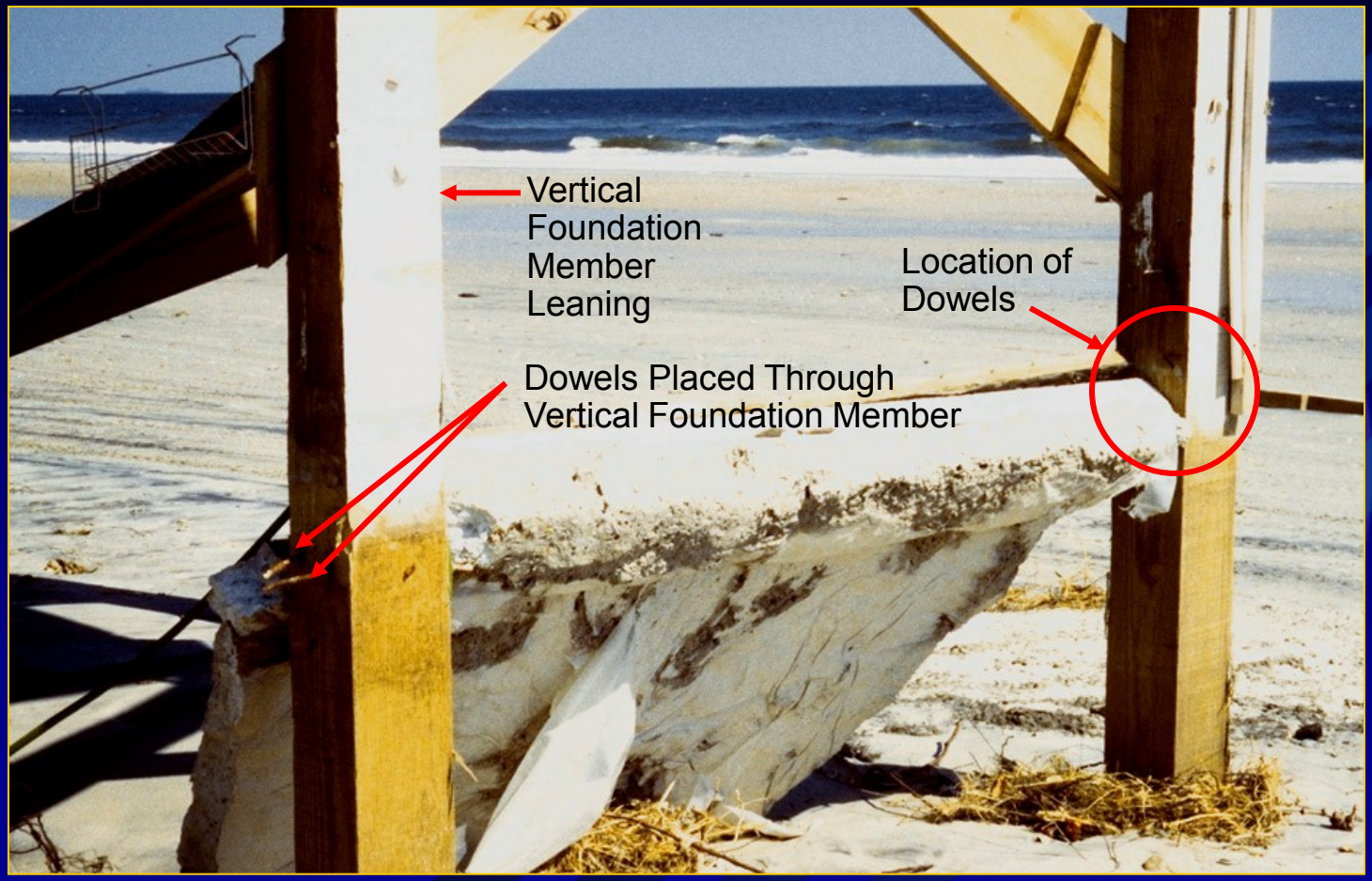
- **Breakaway Walls**
  - Placement seaward of cross-bracing
  - Installation of sheathing continuously across vertical foundation members
  - Attachment methods that prevented breakaway (e.g., too many fasteners)


Cross-Bracing Behind Breakaway Wall
CROSS-BRACING SPLINTERED; FASTENERS HAVE PULLED THROUGH BRACING BECAUSE OF EXCESSIVE LOADING

Observations

- **Below-Building Concrete Slabs**
  - Slabs too thick (i.e., >4 inches)
  - Inadequate number of contraction joints
  - Use of wire mesh in slabs
  - Slabs connected to vertical foundation members


6+ inches


Vertical Foundation Member Leaning
Location of Dowels
Dowels Placed Through Vertical Foundation Member

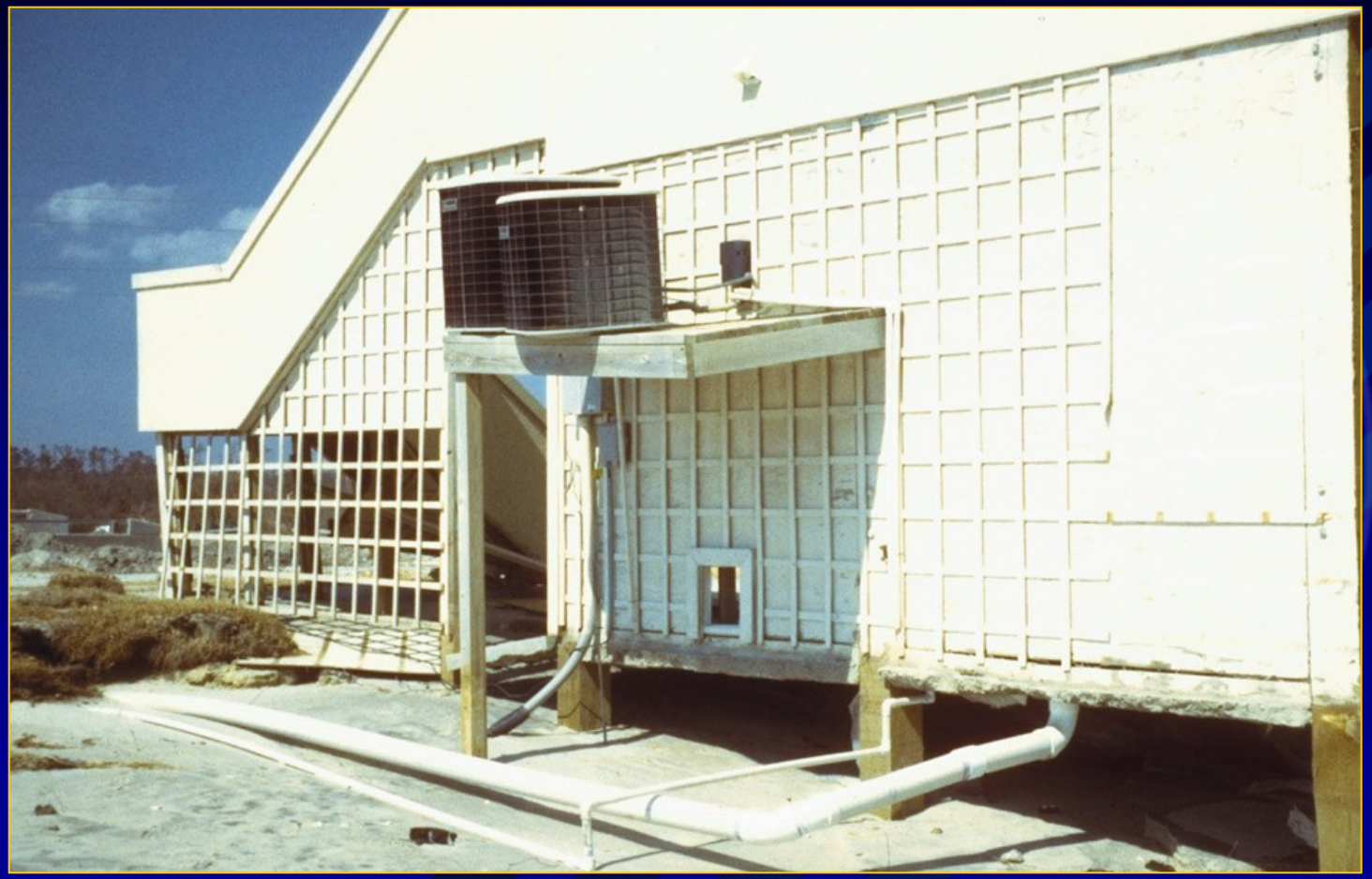
Observations

- **Below Building Concrete Slabs** *(continued)*
  - **Slabs and grade beams cast monolithically**
  - **Use of concrete collars around vertical foundation members to support slabs**

Observations

- On-Site Utility Systems
  - AC/heat pump compressor platform support posts not embedded deep enough
  - Unanchored AC/heat pump compressors
  - System components on or adjacent to breakaway walls

FEDERAL EMERGENCY MANAGEMENT AGENCY



BUILDING PERFORMANCE ASSESSMENT TEAM

FEDERAL EMERGENCY MANAGEMENT AGENCY

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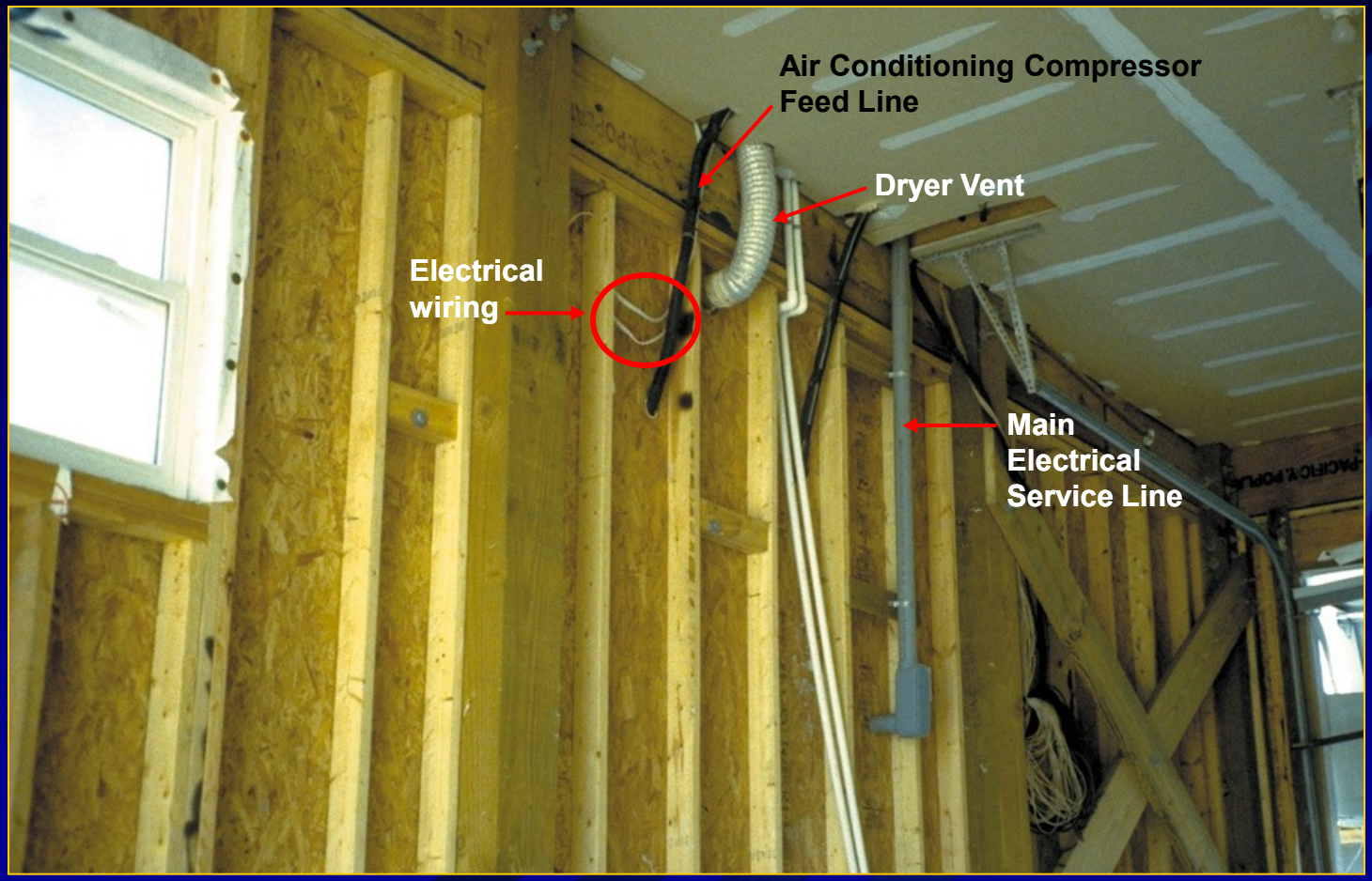
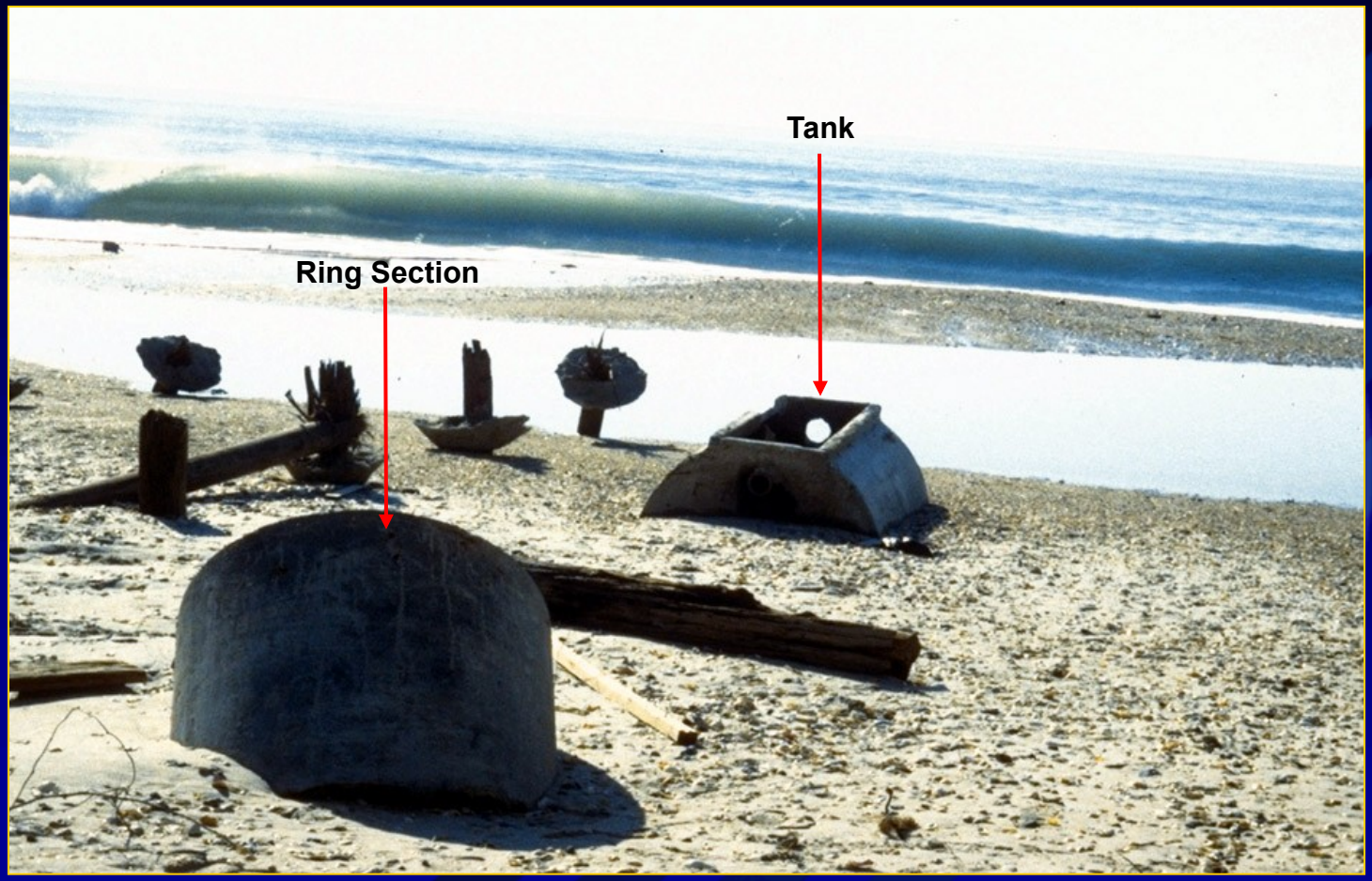
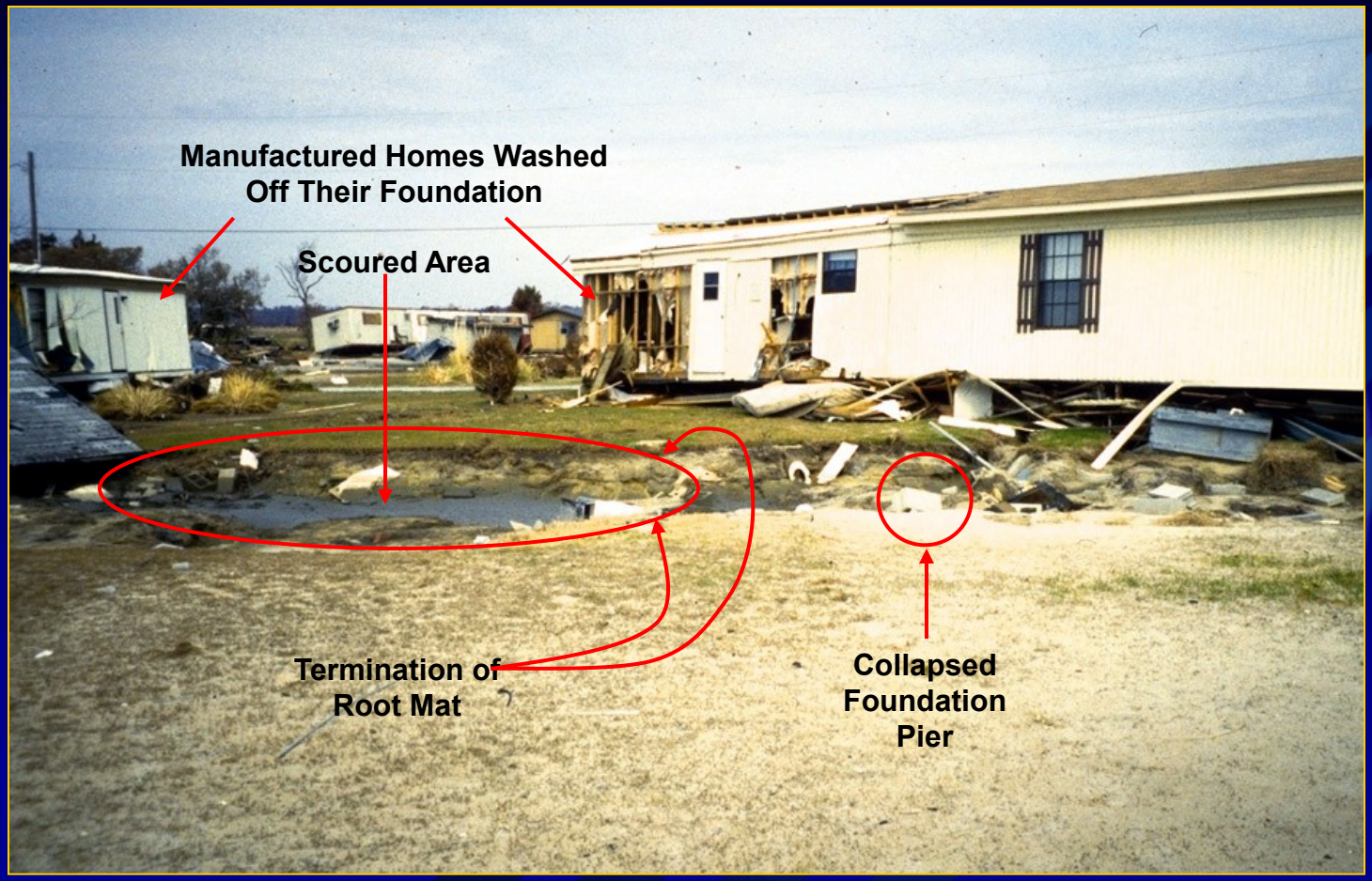
BUILDING PERFORMANCE ASSESSMENT TEAM

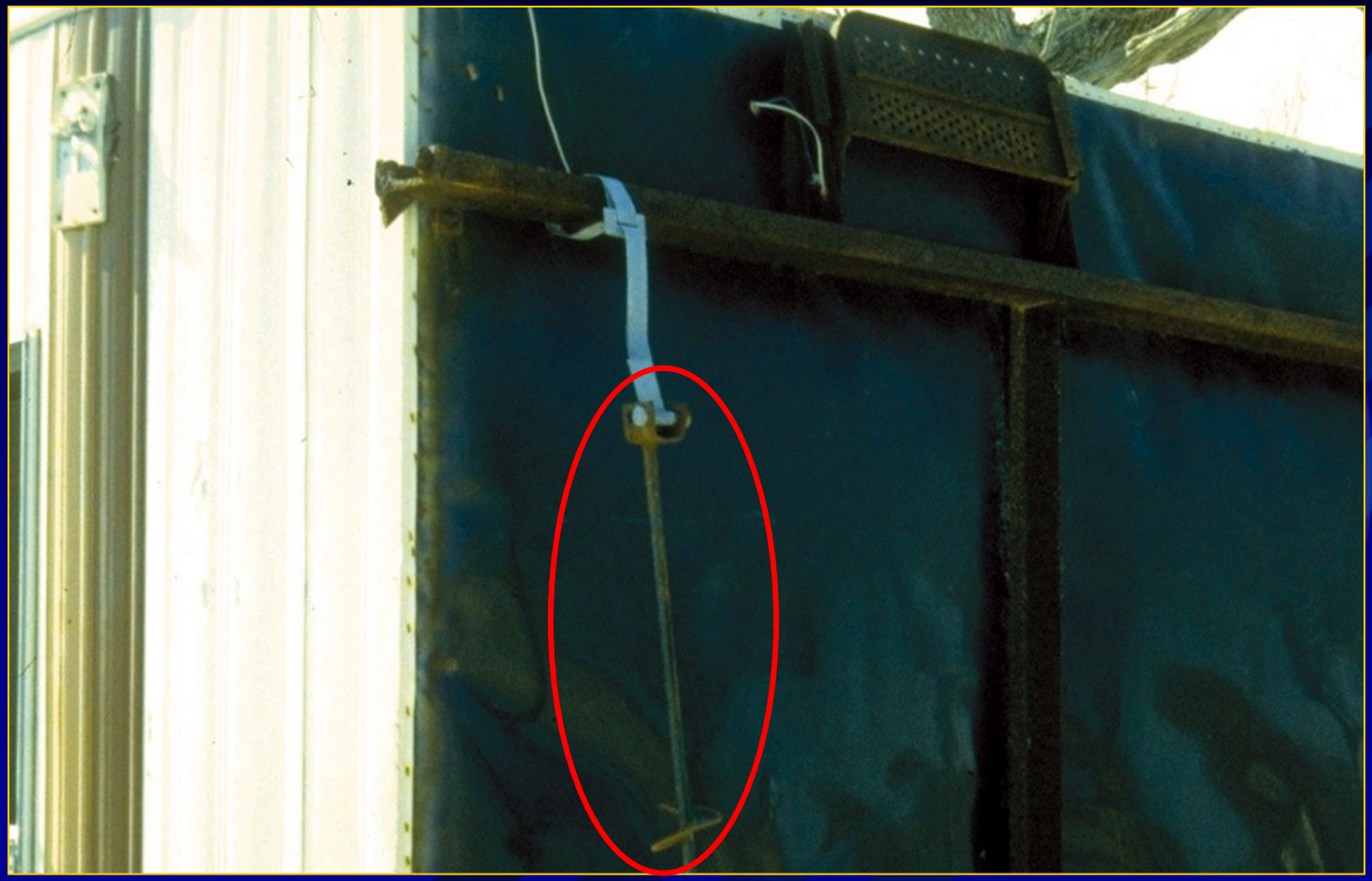

Air Conditioning Compressor
Feed Line
Dryer Vent
Electrical
wiring
Main
Electrical
Service Line

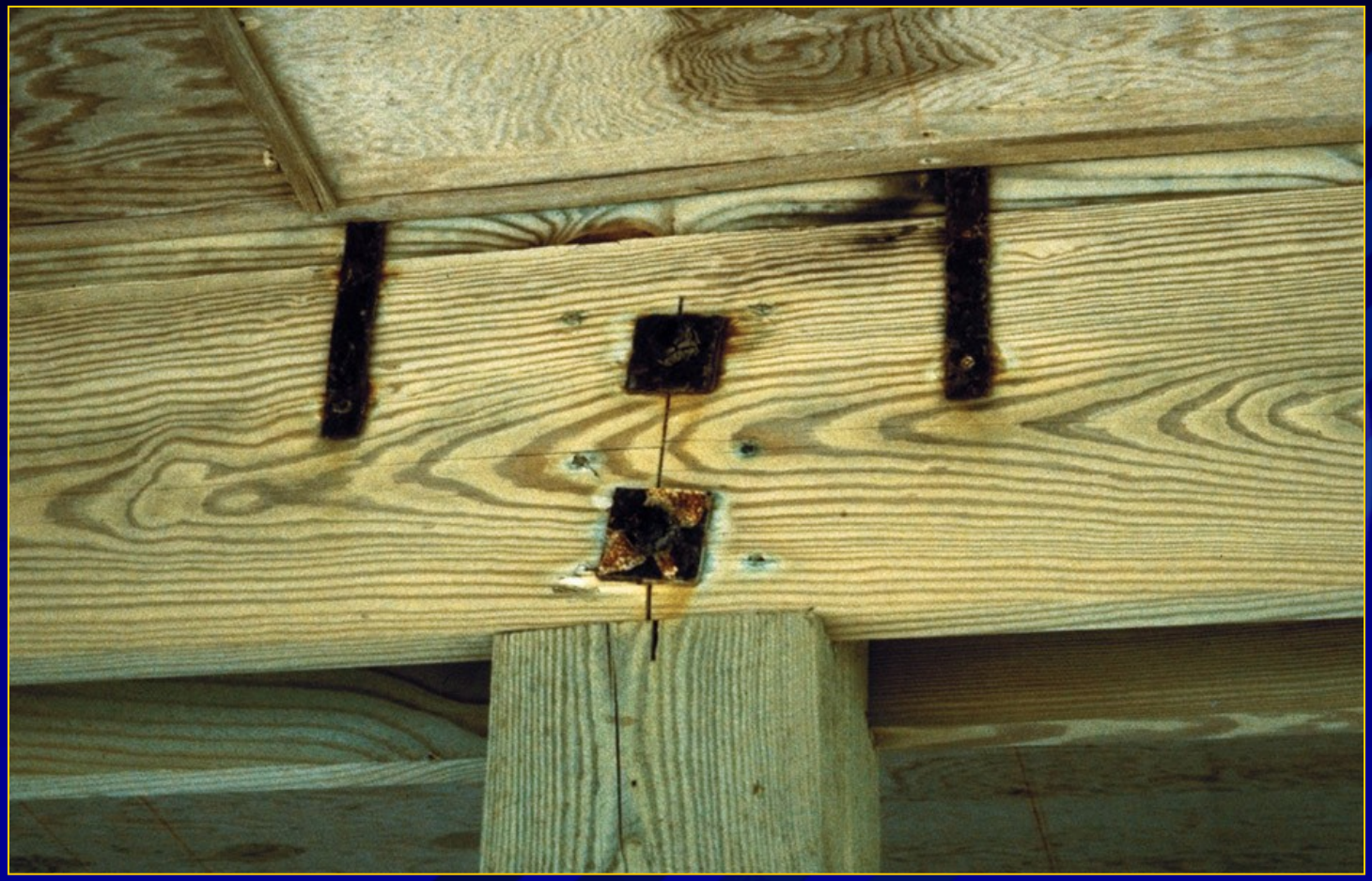
Observations

- **On-Site Utility Systems** *(continued)*
  - System components installed on seaward faces of vertical foundation members nearest ocean
  - Septic tanks installed on ocean side of building


Tank
Ring Section


Manufactured Homes Washed Off Their Foundation
Scoured Area
Termination of Root Mat
Collapsed Foundation Pier





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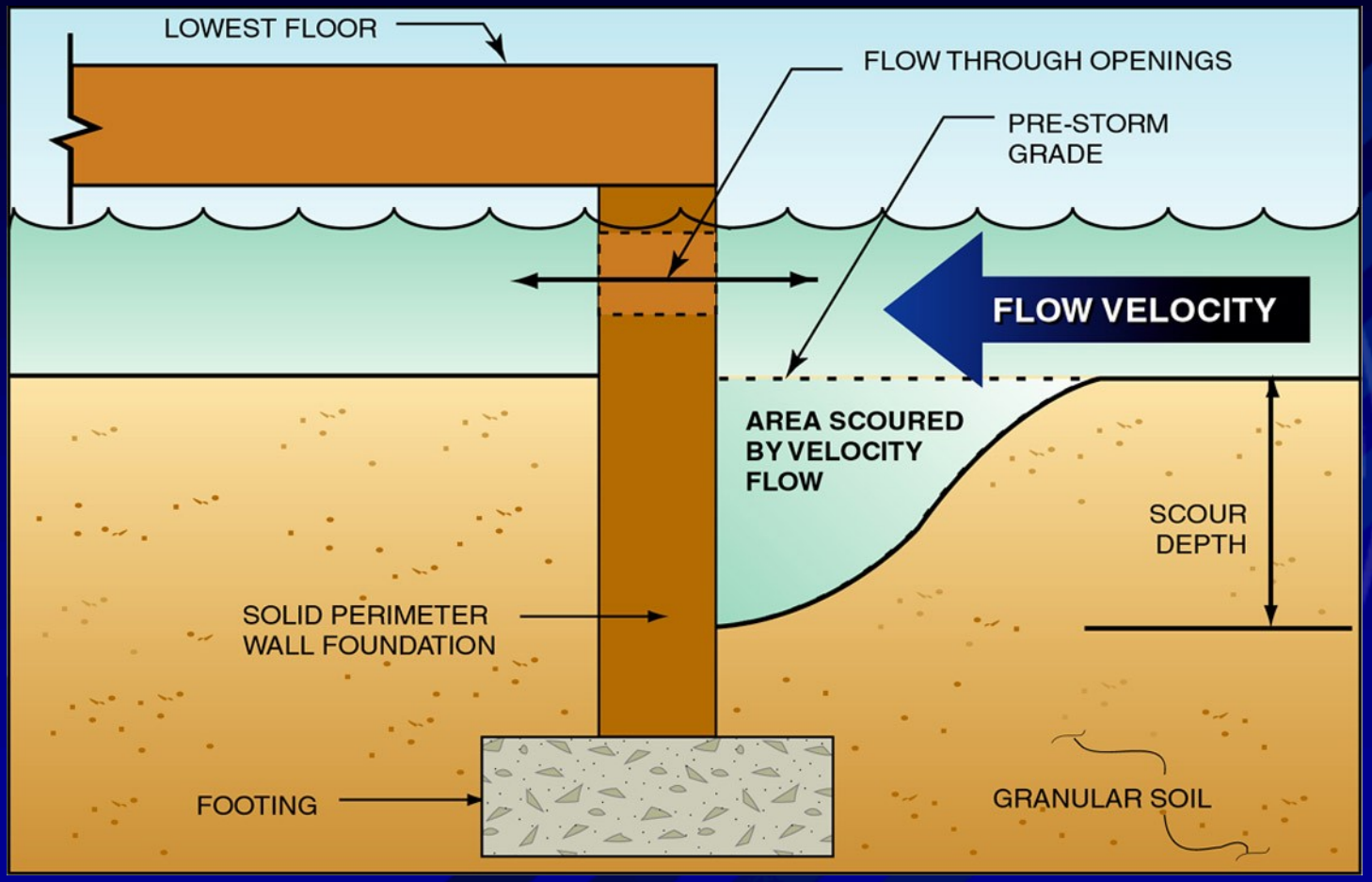
Recommendations

- **Piling and Post Embedment Depths**
  - In absence of State/local requirements, embedment depth for pilings in erosion-prone areas should be -10 feet m.s.l.
  - State of North Carolina should consider requiring embedment of 16 feet below grade or 5 feet m.s.l., whichever is deeper
  - Embedment depths for deck, porch, and roof overhang pilings should be same as for main building


LOWEST FLOOR
FLOW THROUGH OPENINGS
PRE-STORM GRADE
FLOW VELOCITY
AREA SCOURED BY VELOCITY FLOW
SCOUR DEPTH
SOLID PERIMETER WALL FOUNDATION
FOOTING
GRANULAR SOIL

Recommendations

- Other Foundation Issues
  - Design foundations to resist flood/wind forces without cross-bracing
  - Require engineering analysis of potential scour before permitting solid foundation walls in landward areas subject to high-velocity flow

Recommendations

- State and Local Requirements
  - Consider adding code requirements regarding grade of lumber used for pilings and cross-bracing
  - Consider requiring that buildings be elevated above the BFE

Recommendations

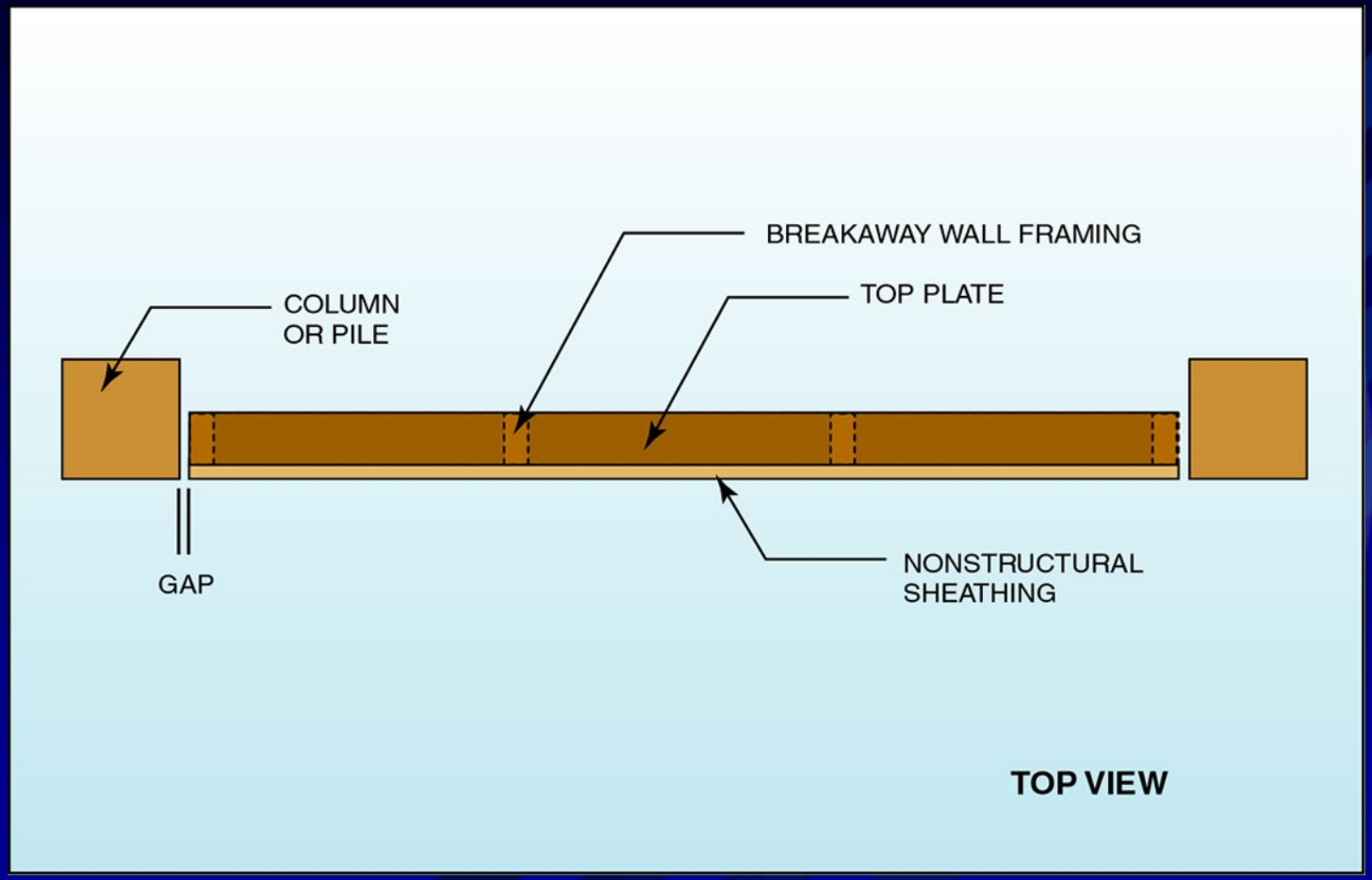
- **Manufactured Homes**
  - **Protect foundation from scour (e.g., geotextile fabric, non-scourable soil, extend below scour depth)**
  - **Periodically check anchor straps for corrosion and proper tension**

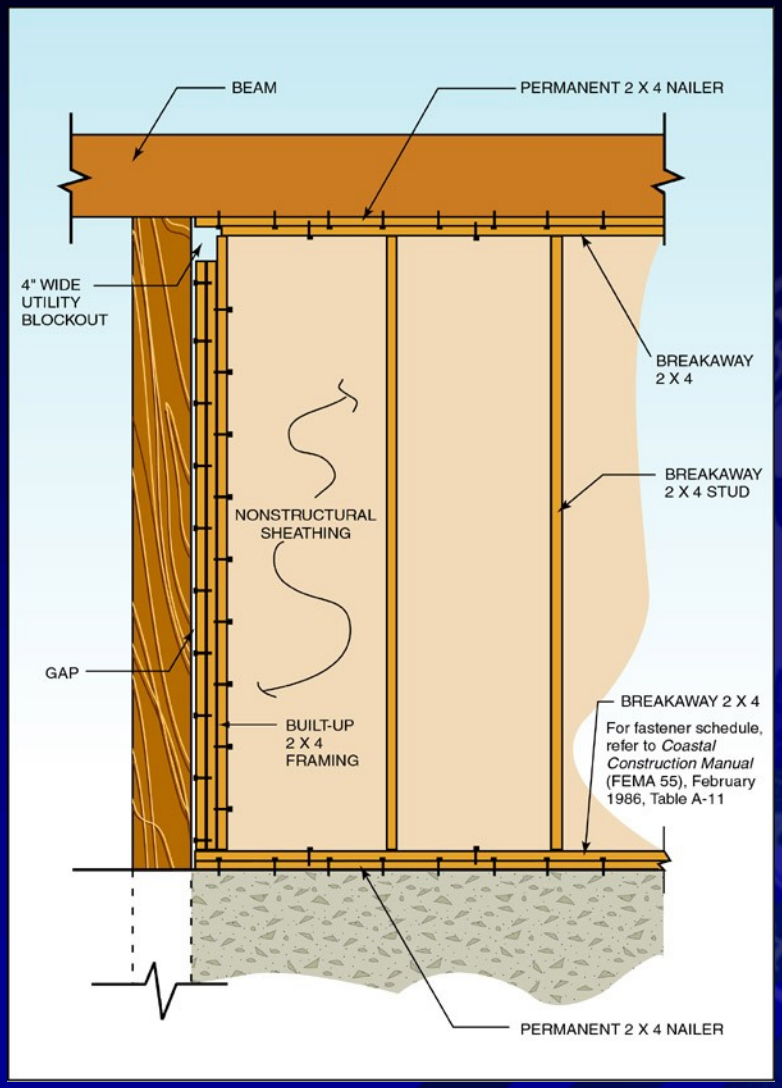
Recommendations

- **Manufactured Home** *(continued)*
  - **Use proper size and type of anchor for soil conditions on site**
  - **In all coastal flood areas, elevate home so that bottom of chassis I-beam is above BFE**

Recommendations

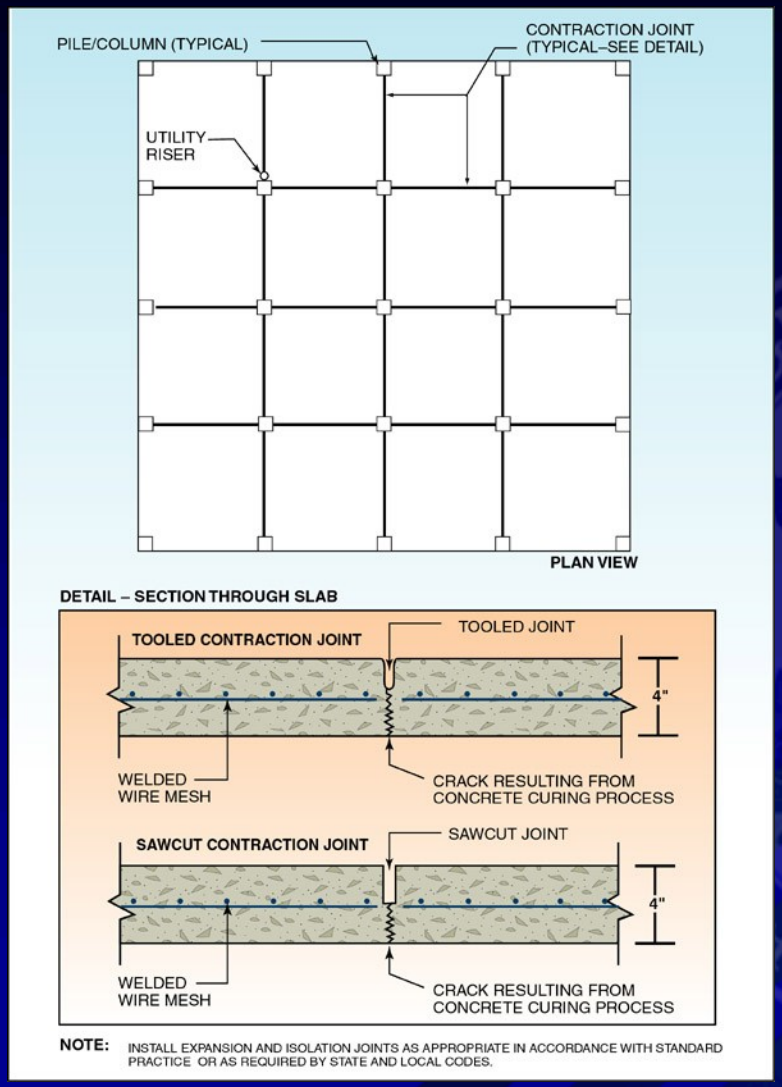
- **Breakaway Walls**
  - Do not extend sheathing across vertical foundation members
  - Attach walls so that they will break away under flood forces
  - Do not install walls immediately seaward of cross-bracing


BREAKAWAY WALL FRAMING
TOP PLATE
COLUMN
OR PILE
GAP
NONSTRUCTURAL
SHEATHING
TOP VIEW


BEAM
PERMANENT 2 X 4 NAILER
4" WIDE UTILITY BLOCKOUT
BREAKAWAY 2 X 4
BREAKAWAY 2 X 4 STUD
NONSTRUCTURAL SHEATHING
GAP
BUILT-UP 2 X 4 FRAMING
BREAKAWAY 2 X 4
For fastener schedule, refer to *Coastal Construction Manual* (FEMA 55), February 1986, Table A-11
PERMANENT 2 X 4 NAILER

Recommendations

- **Below-Building Slabs**
  - **Limit slab thickness to 4 inches**
  - **Install adequate number of contraction joints**
  - **Do not use wire mesh**

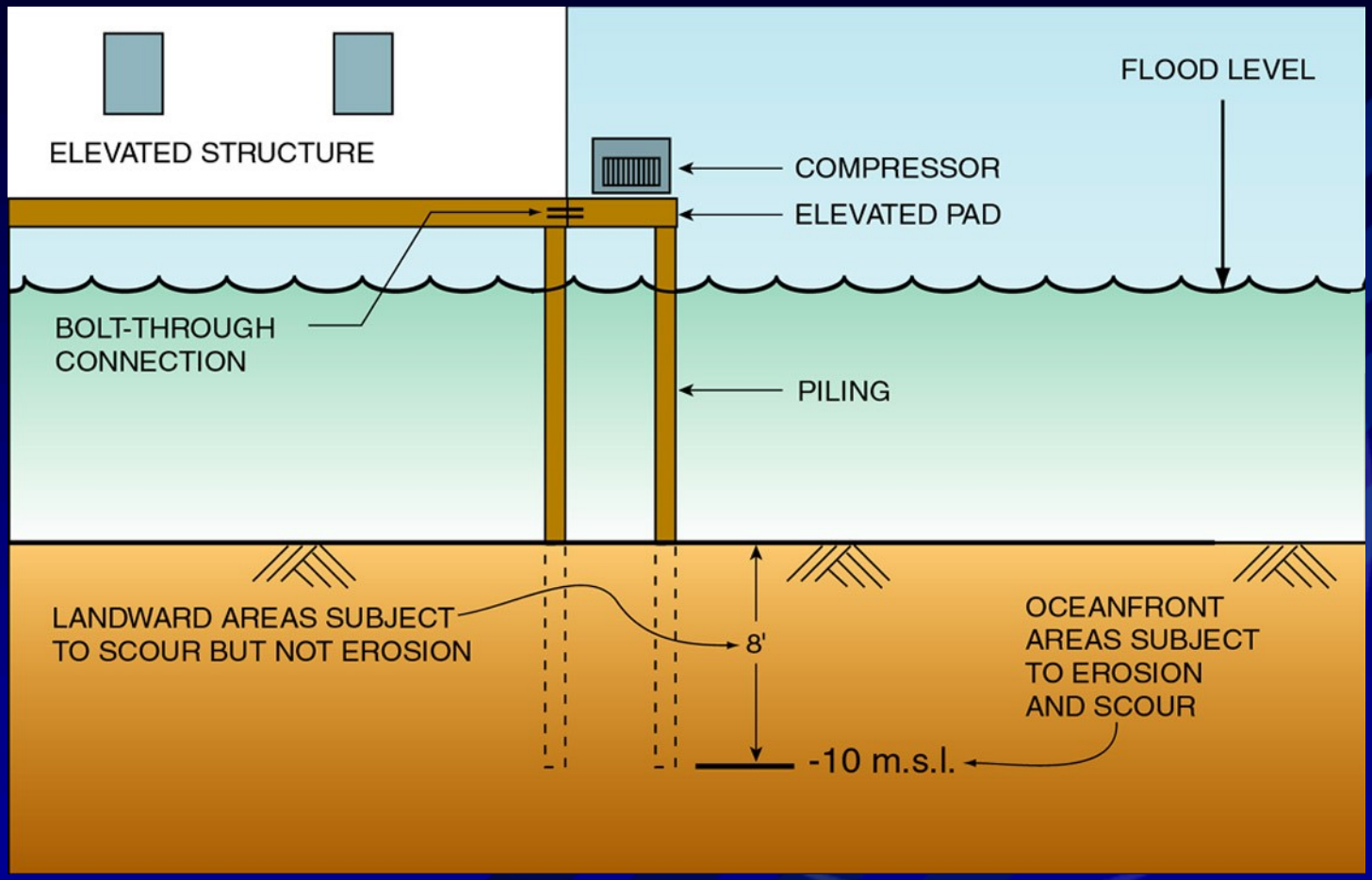

PILE/COLUMN (TYPICAL)
CONTRACTION JOINT
(TYPICAL–SEE DETAIL)
UTILITY
RISER
PLAN VIEW
DETAIL – SECTION THROUGH SLAB
TOOLED CONTRACTION JOINT
TOOLED JOINT
4"
WELDED
WIRE MESH
CRACK RESULTING FROM
CONCRETE CURING PROCESS
SAWCUT CONTRACTION JOINT
SAWCUT JOINT
4"
WELDED
WIRE MESH
CRACK RESULTING FROM
CONCRETE CURING PROCESS
NOTE: INSTALL EXPANSION AND ISOLATION JOINTS AS APPROPRIATE IN ACCORDANCE WITH STANDARD PRACTICE OR AS REQUIRED BY STATE AND LOCAL CODES.

Recommendations

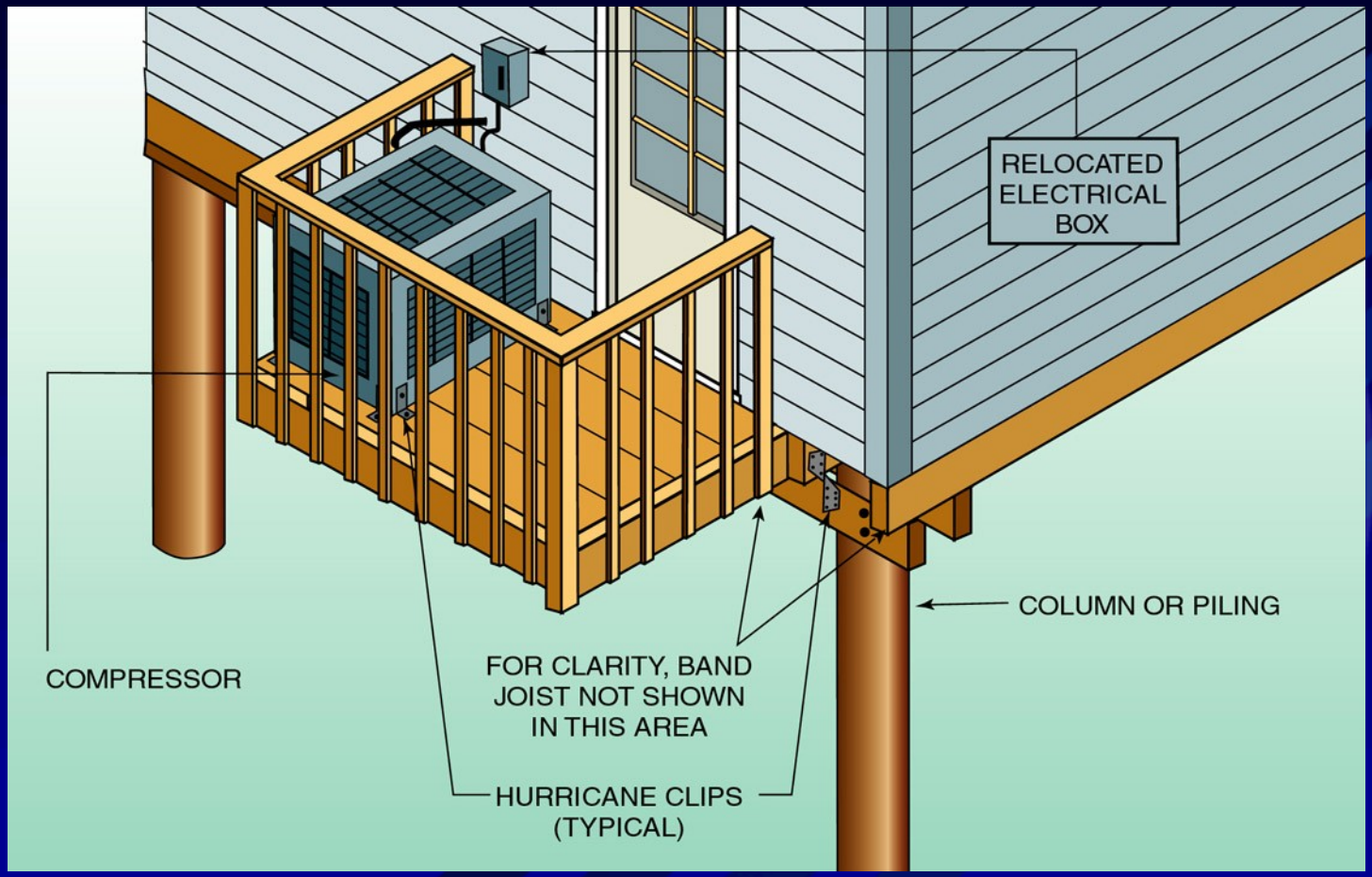
- **Below-Building Slabs** *(continued)*
  - Do not connect slabs to vertical foundation members
  - Do not cast slabs/grade beams monolithically
  - Do not install concrete collars around vertical members under slabs

Recommendations

- On-Site Utility Systems
  - Embed vertical members for AC/heat pump compressor platform to same depth as those for main building, or use cantilever platform
  - Anchor compressor to resist wind

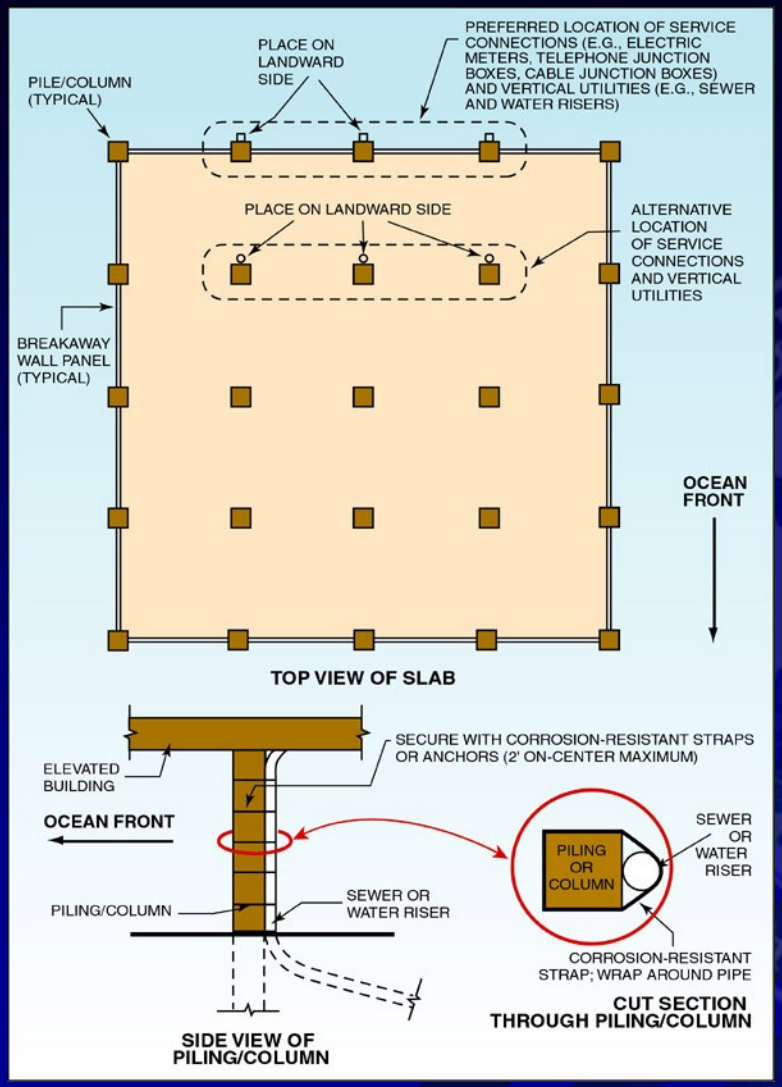


Mechanical platform supported by pilings.


RELOCATED ELECTRICAL BOX
COLUMN OR PILING
COMPRESSOR
FOR CLARITY, BAND JOIST NOT SHOWN IN THIS AREA
HURRICANE CLIPS (TYPICAL)

Recommendations

- **On-Site Utility Systems** *(continued)*
  - Do not place utility system components on, through, or adjacent to breakaway wall panels
  - Locate utility system components on landward faces of vertical foundation members farthest from ocean
  - Locate septic tanks as far landward as possible


PLACE ON LANDWARD SIDE
PREFERRED LOCATION OF SERVICE CONNECTIONS (E.G., ELECTRIC METERS, TELEPHONE JUNCTION BOXES, CABLE JUNCTION BOXES) AND VERTICAL UTILITIES (E.G., SEWER AND WATER RISERS)
PILE/COLUMN (TYPICAL)
PLACE ON LANDWARD SIDE
ALTERNATIVE LOCATION OF SERVICE CONNECTIONS AND VERTICAL UTILITIES
BREAKAWAY WALL PANEL (TYPICAL)
OCEAN FRONT
TOP VIEW OF SLAB
SECURE WITH CORROSION-RESISTANT STRAPS OR ANCHORS (2' ON-CENTER MAXIMUM)
ELEVATED BUILDING
OCEAN FRONT
PILING/COLUMN
SEWER OR WATER RISER
SIDE VIEW OF PILING/COLUMN
PILING OR COLUMN
SEWER OR WATER RISER
CORROSION-RESISTANT STRAP; WRAP AROUND PIPE
CUT SECTION THROUGH PILING/COLUMN